

R-F TRANSMITTER MODULAR SUB-ASSEMBLIES

**BI-MONTHLY PROGRESS REPORT NO. 1
JULY 1, 1957 TO SEPTEMBER 1, 1957**

CONTRACT NO. NOas 57-1034-c

U. S. NAVY

Bureau of Ships

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**DCN NO. W-038
Copy 1 of 8 copies
Consisting of 12
pages and 8 figures**

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1. SUMMARY

This report is a review of the first two months of the engineering program.

R-F circuit design and development for the 3 to 5.4 Mc 1/2 watt A1 emission system is discussed. Electro-mechanical devices necessary to accomplish the sub-miniature design are described.

Progress to date, problems encountered, and plans for the future are revealed.

2. INTRODUCTION

The objective of the initial phase is to perform the major portion of the basic engineering development required, and to produce a final set of highly miniaturized, highly reliable type A1 emission modules for 1/2-watt low frequency band operation. The approach thus far has been to proceed with the design and development of the necessary circuitry for 1/2-watt A1 emission over Band No. 1, 3.0 to 5.4 Mc. An experimental modularized model system has been constructed utilizing the circuits that appeared most promising at the time of construction.

3. R-F CIRCUIT DESIGN AND DEVELOPMENT

3.1 Transistor Circuits

The original rf oscillator breadboard design was essentially that of Fig. 1. After a paper study, this circuit was chosen for experimentation for several reasons. The first is that the CR-18/U crystal unit is a parallel resonant type, and therefore presents a high impedance at its resonant frequency. Transistor oscillator theory tells us that one of the ways in which oscillations may be produced is by increasing the value of the external base impedance at resonance. The use of the CR-18/U in the base circuit satisfies this condition. Secondly, this circuit may readily be modified to provide frequency multiplication by tuning tank L1 - C6 to a harmonic of the crystal frequency. The collector circuit impedance remains relatively low at the fundamental frequency. This is a second condition for facilitating oscillation. After optimizing the circuit, the effectiveness of the crystal as the frequency controlling element was tested by detuning L1 - C6 on both sides of resonance with a 50 ohm resistive load connected to L2. Slight frequency changes due to detuning distortion were noted, but no radical changes occurred. With the crystal removed from the socket no rf output could be detected. The circuit was tested over the frequency range of 3 Mc to 6 Mc with an RCA Developmental Type TA-1629 drift transistor. This transistor is being marketed as a 2N384. Philco Developmental Types L5405 and L5406 (graded base transistors) have also been tried in this circuit with similar results. Power outputs ranging from 5 mw to 20 mw with efficiencies of 10% to 30% have been obtained. Figures 4a and 4b show this circuit packaged into a one-inch cube. In Fig. 4b the tuning control can be seen on the right side beneath the power leads. After the contracting agency's representative requested

that we investigate the possibility of reducing the number of tuning controls, it was decided to attempt to eliminate this control. This means that the only requirement for the operator to change frequency in the oscillator module would be to plug in a different crystal. It was found that the base controlled circuit of Fig. 1 could be converted into a wide band oscillator by making the tank circuit resonant at the low frequency end of the band, and by optimizing other circuit elements such as feedback capacitor C5 for the least distortion and constant power output over the band. One such circuit with an RCA Type TA-1629 delivered 5 mw into a 50 ohm load crystal controlled at either 3 Mc or 5 Mc. It oscillated crystal controlled at 10 Mc, but delivered only 1-1/4 mw of power.

On the basis of experience gained thus far about crystal controlled transistor oscillators recommendation has been made through our Contract Administration office for authorization of several changes in the contract specifications. Specification 2.3. Crystal Control would read ". . . whose fundamental frequencies range from 3 Mc to 15 Mc . . . by utilizing the Armed Forces crystal units, CR-18/U or CR-19/U". Delete "the oscillator input capacity . . ." and replace with "the crystal shall operate within its rated operating characteristics as specified in WADC Technical Report ⁽¹⁾ 54-248". The use of 15 Mc crystals rather than 10 Mc units as originally specified allows 30 Mc operation to be reached by frequency-doubling rather than frequency-tripling techniques. This results in greater efficiency, and therefore makes less stringent the power requirements of the rf transistor stages. 15 Mc units are readily available in either the CR-18/U or the CR-19/U types. The addition of the CR-19/U series

1. Buchanan, J. P., "Handbook of Piezoelectric Crystals for Radio Equipment Designers"

resonant type unit as a choice in crystals gives the designer a better selection of circuits for trial. A survey of transistor oscillator literature revealed a ratio of 2 to 1 between series resonant type crystal controlled oscillators to the parallel resonant type. The final choice of crystal unit would depend on an analysis of performance specifications test results.

Plans for the next period (2 months) are to continue development of the CR-18/U wide band oscillator circuit utilizing the RCA Type TA-1629 and Philco L-5405 and L-5406 transistors. The frequency range of design will be extended to 15 Mc. Oscillator circuit design and development applying the CR-19/U crystal unit will be initiated. The contracting agency is to furnish four Western Electric Type GA-53233 transistors for experimentation. Preliminary environmental tests will be performed. If necessary, the design and development of a transistorized amplifier-multiplier will be initiated. Thus far 1/2 watt system tests have shown that frequency pulling on the crystal controlled oscillator by the keyed power amplifier is very slight and well within the output frequency tolerance.

3.2 1/2 Watt Power Amplifier

The power amplifier must be capable of producing 1/2 watt of power at the antenna terminals after losses in the VHF suppressor and antenna coupling system. Early studies disclosed that the overall efficiency of the amplifier to antenna connecting system could be as poor as 60%. Therefore, the initial design goal for amplifier power output was 1 watt over the frequency band of 3 to 5.4 Mc. The possibility of using transistors in this stage was ruled out until more can be learned about the higher rf power transistors now being developed. Investigations are continuing in this direction. The second choice for the application was the Eitel-McCullough ceramic tubes. A recent reply from the manufacturer concerning their status states that they are not ready for release. They have been in the development stage for more than a year. This left only the sub-miniature tube line to select from. The first breadboard design utilized the Raytheon CK 6397 filamentary type sub-miniature beam pentode. This filamentary tube was chosen because it would produce less of a heat dissipation problem when encapsulated. Being a pentode it would also create less of a neutralization problem when 30 Mc amplifier design is attacked. In an experimental circuit similar to Fig. 2 operation Class C, this tube developed a maximum of 0.7 watt in a 50 ohm load connected to L4 with the circuit optimized for maximum power output over the low band frequency range. Transformers T1 and T2 were designed for small size and the best input and output impedance matches that could be obtained without allowing loaded Q's to drop below 10. Permeability tuned transformers of small size are used instead of variable capacitors to keep the required tank volumes to a minimum. The transformer coil forms are discussed further in the mechanical design Section 4.2. To deliver more power

to the 50 ohm load, the experimental circuit was redesigned around a premium cathode type sub-miniature CK 5639 pentode. The circuit of Fig. 2 when optimized and operating Class C can deliver as much as 1-1/2 watts to a 50 ohm load. Its plate efficiency of 40% is rather poor for a Class C amplifier. It has been attributed thus far to being unable to match the high plate resistance of the tube with the miniature tank design necessary for the application. Further development is continuing with this circuit. The immediate objective in mind is to eliminate the tuning of L2. Experimentation with wide-band toroidal and cup-core transformers is being performed to reach this goal. The possibility of using this circuit with tank modifications to connect two modules for 5 watt output is being investigated. An experimental modular package of the circuit of Fig. 2 is exhibited in Fig. 5. It is a 2-inch cube. For temperature testing, a 5639 tube has been encapsulated in a 2-inch cube of Ciba Araldite 502 resin with an Epon U catalyst. With tube power consumption of approximately 6 watts, the tube surface temperature rose to 190° C., and the external surface temperature of the module measured 51° C. A second experimental amplifier module in a 1-1/2 inch cube is being packaged.

Excitation keying of the blocked grid form has been employed in testing the circuit of Fig. 2. Keyed envelopes have been free of key clicks, and have well rounded corners on the leading and trailing edges. The major disadvantage of this form of keying is the large negative bias required for blocking the grid when the key is open. Experimentation is being continued on other forms of keying such as cathode bias. The objective is to avoid the use of a negative bias supply.

Early attempts at powering a side-tone 1 kc transistor oscillator from the

amplifier output tank proved the idea to be impractical in this application.
The transistor oscillator frequency and amplitude stability vs. rf frequency
were very poor.

3.3 Antenna Coupling System

After a period of study of the antenna matching problems involved, experimentation was started with the 3 to 5.4 Mc antenna coupling system in Fig. 3. A packaged module based on this system is displayed in Fig. 6. The system serves a two-fold purpose. Namely, to cancel any antenna reactive component ranging from 40 to 1200 ohms, either capacitive or inductive, and to match the 50 ohm input transmission line impedance to any resistive load ranging from 40 to 1200 ohms. Preliminary testing of this circuit revealed an overall power transfer efficiency of approximately 75% at a frequency of 4.0 Mc and 5 watts output. Power output dropped less than 5% at the end limits of the frequency range. This test was performed at the 5 watt level to check the immediate effects of the highest rf circulating currents on the performance characteristics of the ferrite cores in the coils. Further electrical and mechanical evaluation of this module will be performed. An effort will be made to reduce the number of tuning controls, but this does not appear promising at present. The 5.4 to 9.5 Mc system is breadboarded and initial tests indicate satisfactory performance. An impedance transformer for the 9.5 to 17 Mc band has been designed, and preliminary data shows efficient operation in this range. A VHF suppressor has been designed, and has progressed to the breadboard stage. It has a 50 ohm input and output impedance. Development will continue on extending the frequency range of the antenna coupling system.

4. ELECTRO-MECHANICAL DESIGN AND DEVELOPMENT

4.1 Miniaturized Hand Key

Two miniature keys have been designed, and an experimental model of each fabricated. The key on the right of Fig. 7 is a scaled down version of a standard key. It has been tested by an experienced operator, and according to him, has a "feel" very much like a normal key. This design can still be reduced in size without destroying the "feel". It was intended that this key would plug into a module as shown in the sketch in Fig. 8A. It could be plugged in as shown in Fig. 8B, or made an intimate part of the module in the same manner. A major disadvantage of the plug-in method of Fig. 8A is that the key would have a tendency to bounce when the operator is using it because of its light weight. The second plug-in method is suggested as a way of overcoming this problem. The key on the left of Fig. 7 is simply a push-button type switch with a key knob attached. It had a very poor "feel", and it is felt that it would be very difficult to reproduce a normal key "feel" with this type of design. It was intended to be encapsulated in the module as shown in Fig. 8C. A major disadvantage of this arrangement is that the key knob surface would be at a much higher level above the operator's arm rest surface than the 1-3/8 inches normally encountered. The operator would probably have to raise the level of his arm rest surface to preserve the comfortable feeling necessary for rapid and tireless keying. A third design is nearing completion. It is a compromise incorporating the desirable features of the first two models.

4.2 Miniature Tunable Coil Forms



To get tunable inductors with wide inductance ranges and high Q's over the tuning range, several slug tuned coil forms have been designed and fabricated for use in the experimental modules. These can be seen in the Figures 4, 5 and 6 in line with the knurled tuning knobs. Small size and reliable hand tuning were emphasized in the design. A considerable degree of success has been gained in machining ferrite rod materials into tunable slugs. Thus far the process has been to drill a hole longitudinally through the center of the ferrite slug, and fill it with an insert that can be drilled and tapped. A chord section is then cut away the entire length of the slug to produce a flat surface on the outside. The slug is placed in a tubular coil form with the end closed. Then a threaded shaft is fed into the slug insert. A pin is placed through the coil form to rest against the flat surface of the slug and prevent it from turning as the tuning shaft is rotated. One machinist has found it possible to tap the slug itself, thereby eliminating the necessity of the insert. These inductors have proven very valuable as time savers in the electronic evaluation of rf circuits.

A slide type variable inductor has been designed and fabricated. It is shown in Fig. 6 in line with the 3 inch mark on the scale, and designated as L3 in Fig. 3. It will be evaluated mechanically and electrically during the next period.

4.3 Miniature Dual-Control Multi-Contact Switch

A switch designated as S1 in Fig. 3 has been designed, and an experimental model has been fabricated. It is located on the top plate of the antenna coupling module in Fig. 6. It is unique in that it is built into a piece of epoxy glass laminate. Dual control is obtained by placing two sets of contacts in concentric circles on the base plate, and using two concentric shafts for wiper control. A smaller and improved version of this switch has been designed, and is in the fabrication stage. It has been designed so it can be encapsulated within the module. Upon completion it will be evaluated mechanically and electrically.

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 Contract Administrator Manager, Engineering

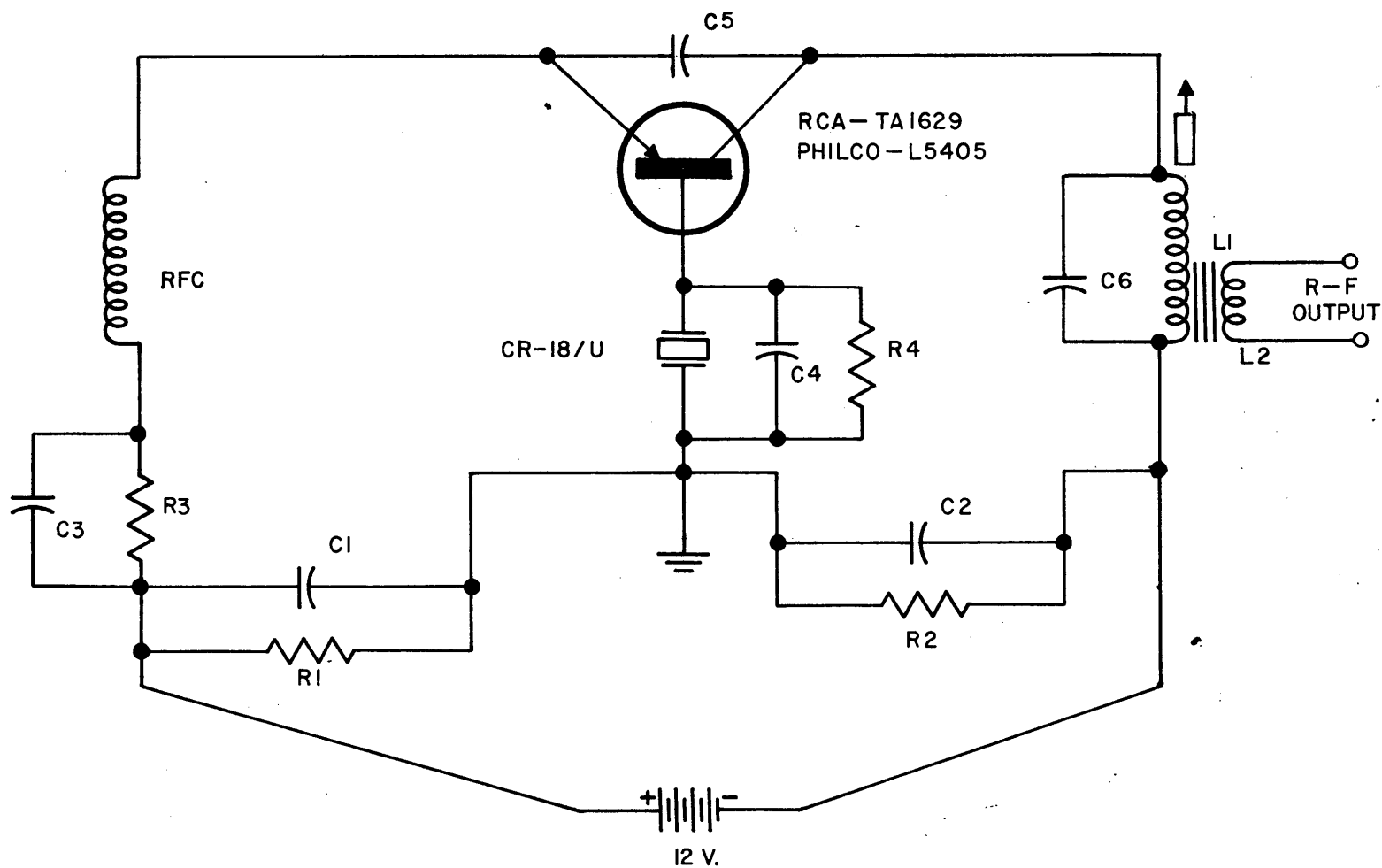


FIG. 1
TRANSISTOR R-F OSCILLATOR

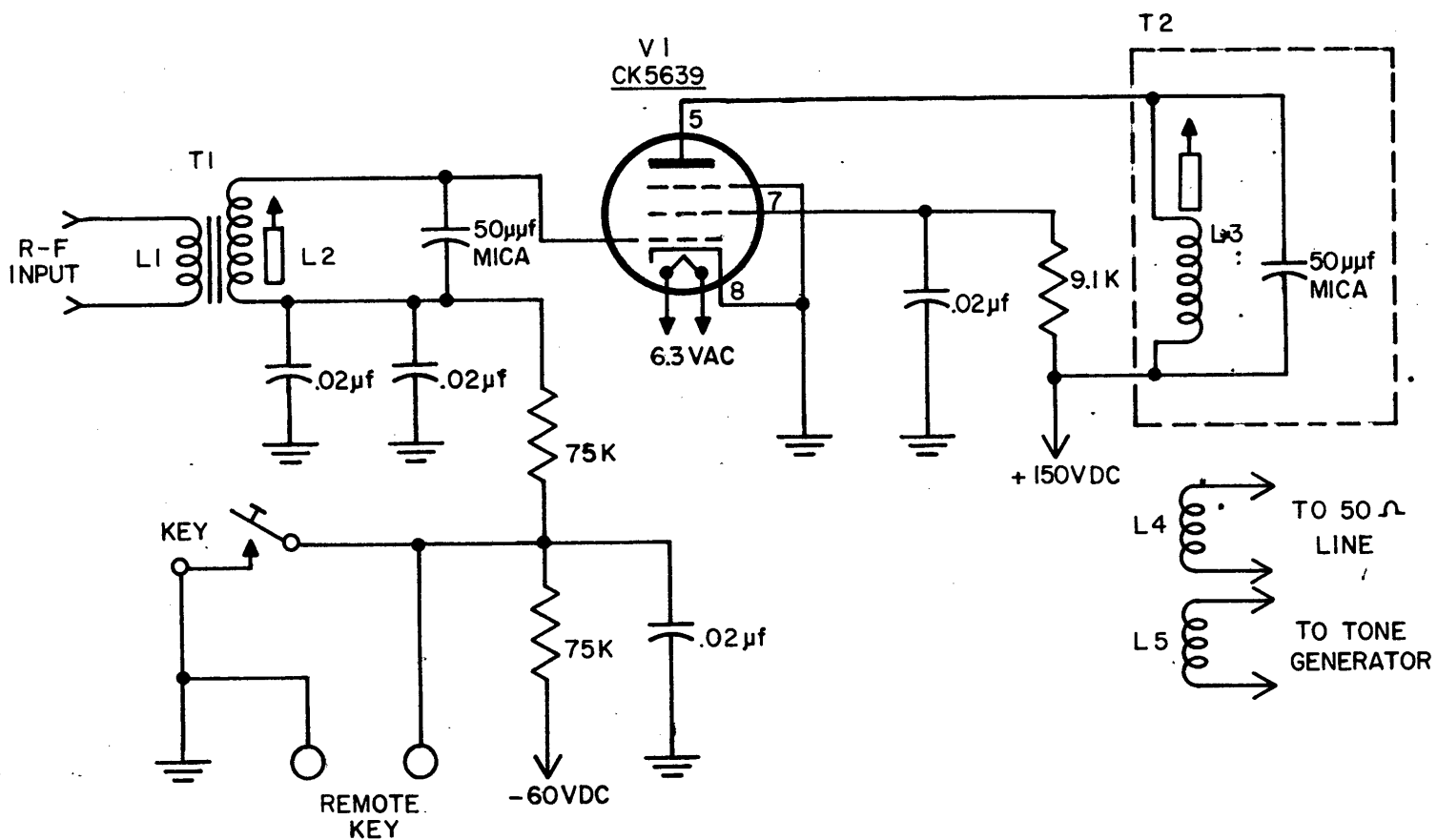


FIGURE 2
1/2 WATT POWER AMPLIFIER

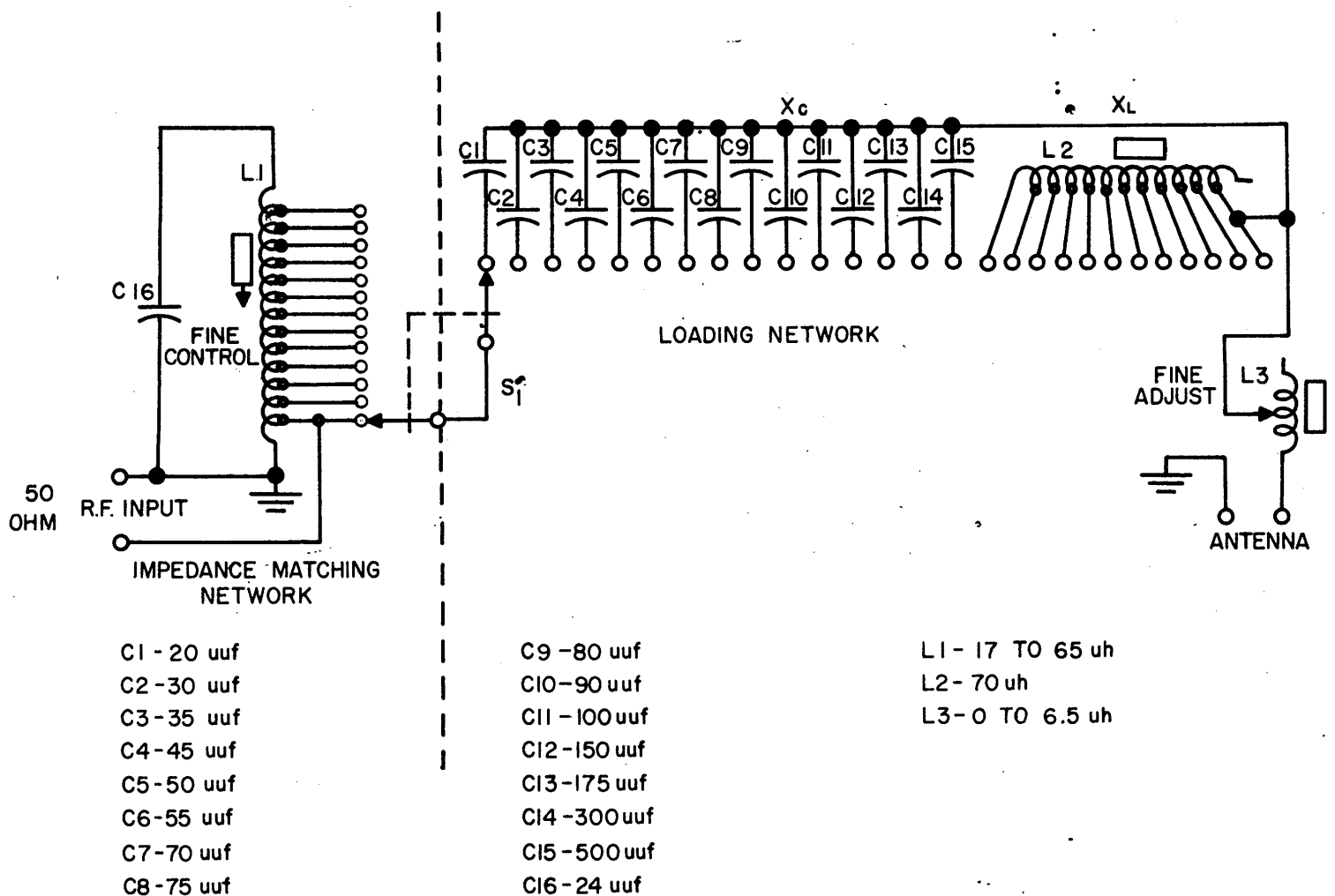


FIG.-3
ANTENNA COUPLING SYSTEM

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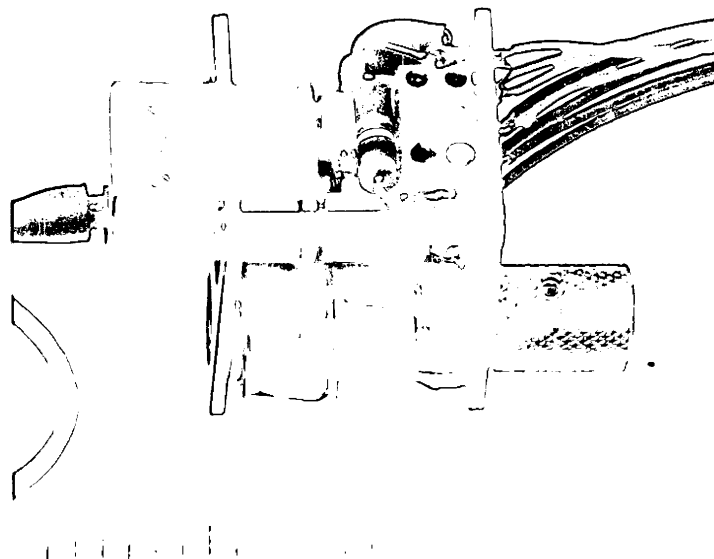
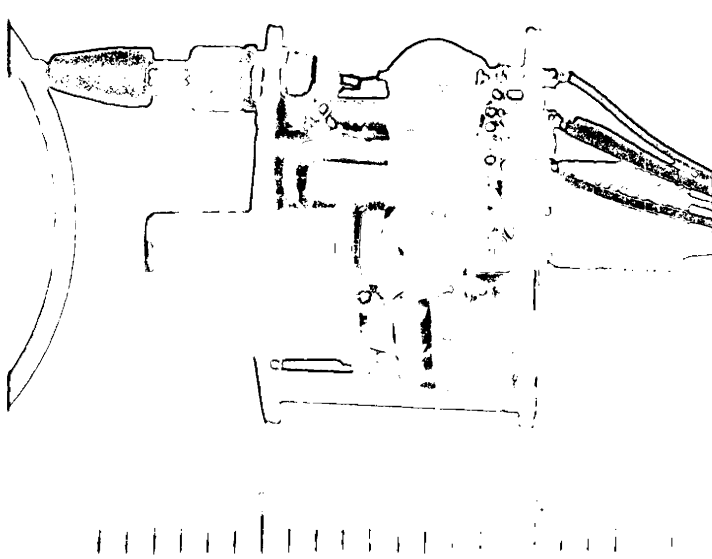


FIG. 4a. TRANSISTOR R-F OSCILLATOR MODULE

FIG. 4b. TRANSISTOR R-F OSCILLATOR MODULE

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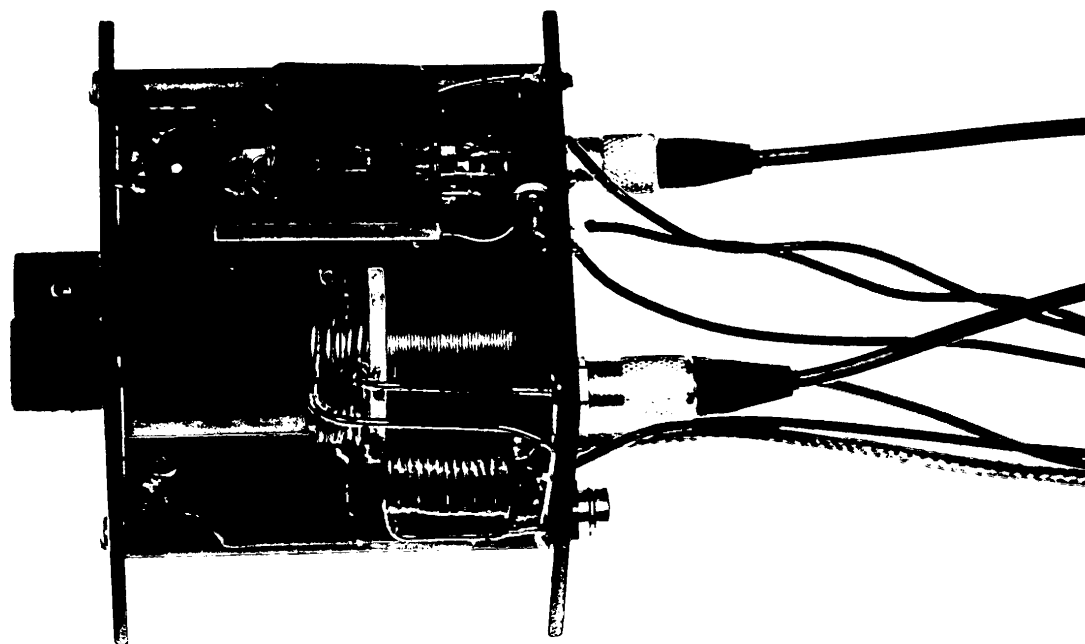


FIG. 5 1/2 WATT POWER AMPLIFIER MODULE

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FIG. 6 ANTENNA COUPLING MODULE

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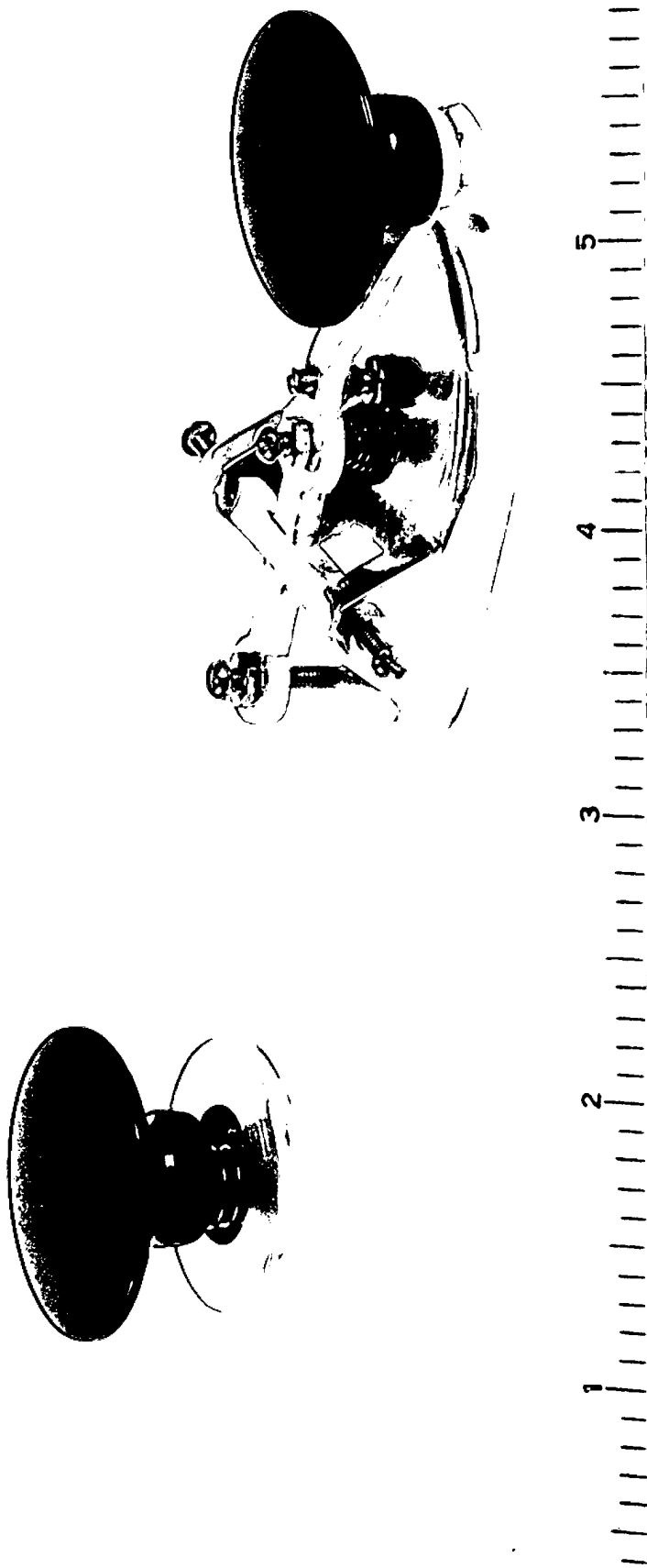


FIG. 7 MINIATURE KEYS

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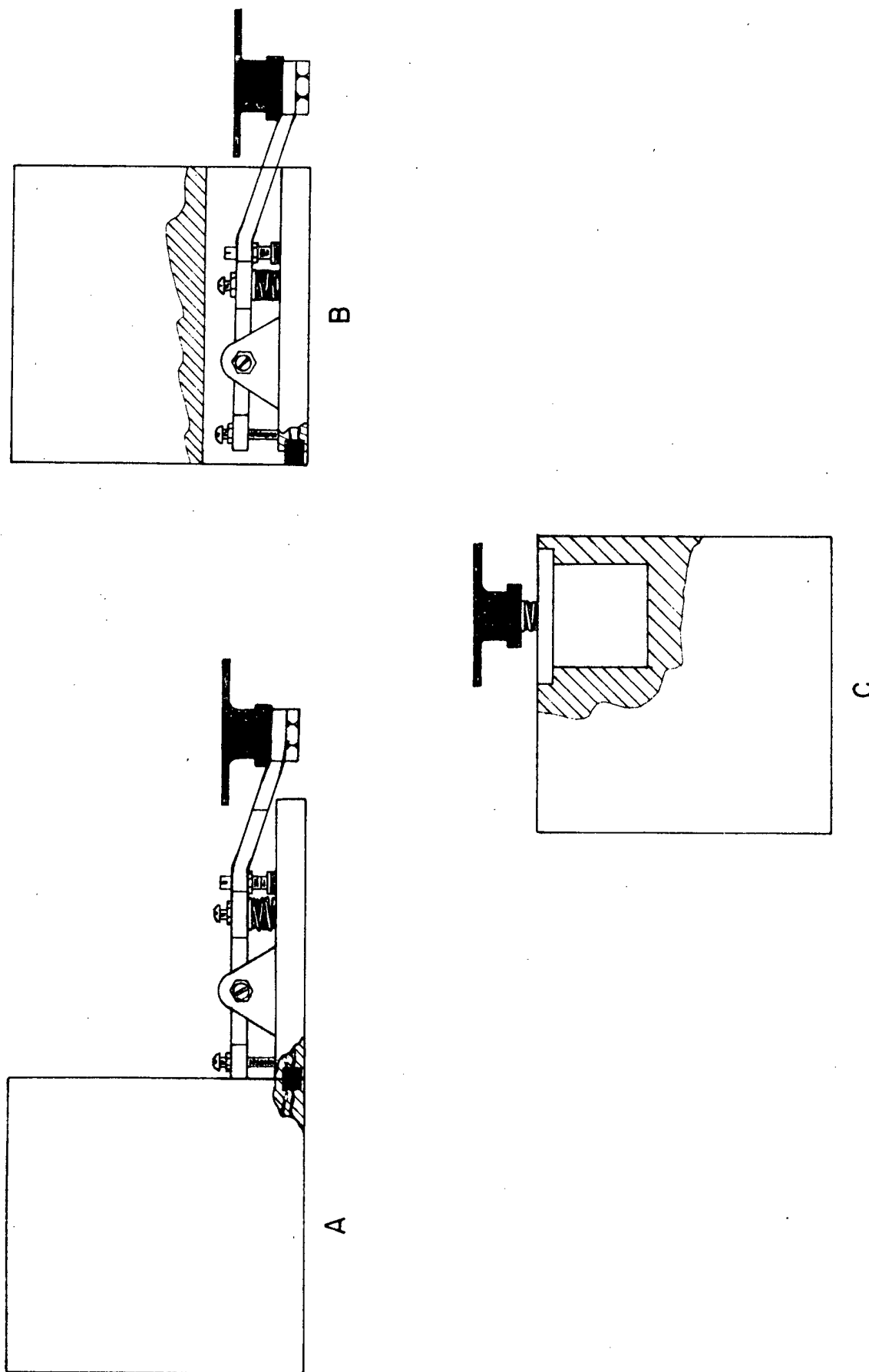


FIG. 8 KEY MOUNTING METHODS

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